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INT CL⁴ **H04R**

(54) **Ultrasonic transducer**

(57) A broadband ultrasonic transducer (10) comprises a folded zig-zag of polyvinylidene fluoride film (12) of between 3 and 10 layers (optimally 5) clamped between a backing block (14) and a coupling block (16). Each surface of the film (12) is coated with a thin gold layer, electrical contact to these layers being made by a spring-loaded probe (32). The coupling block (16) may contact the film (12) only along a narrow ridge (30), so as to create a well-defined line source of ultrasound. The transducer can provide ultrasonic pulses of very short duration, so enabling good time resolution to be achieved.

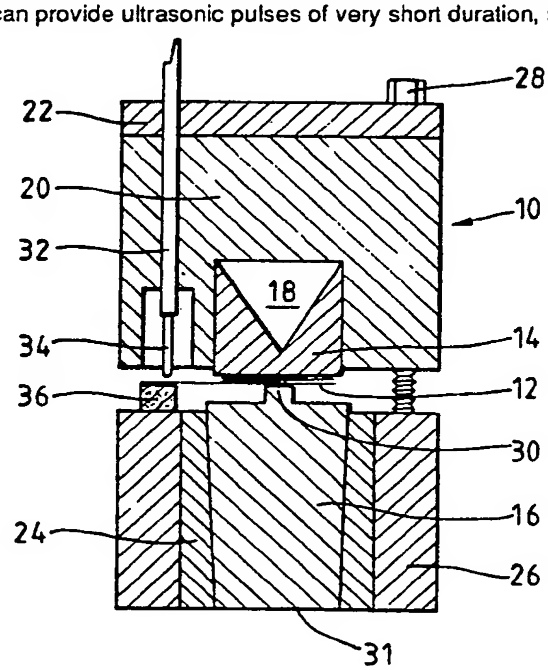

Fig.1.

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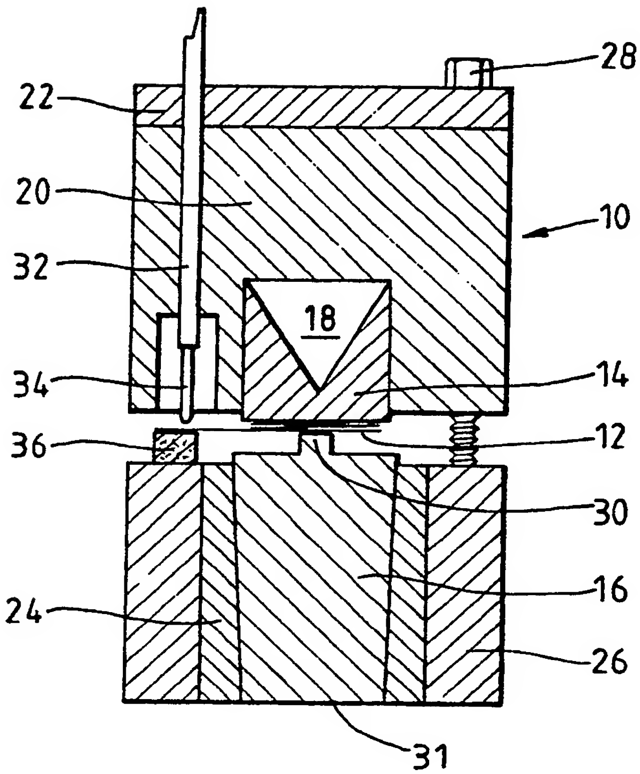

Fig.1.

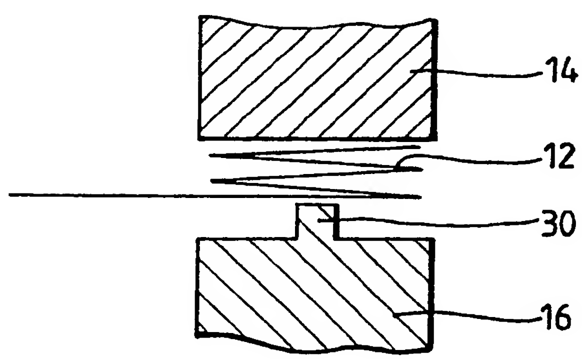

Fig.2.

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Ultrasonic Transducer

This invention relates to ultrasonic transducers, and in particular to transducers which utilize the piezoelectric effect.

It is well known that many inorganic solids, such as quartz and tourmaline, exhibit the piezoelectric effect, that is that when subjected to an electric field they undergo a mechanical strain and vice versa; a piezoelectric material commonly used in ultrasonic transducers is the ceramic lead zirconate titanate (PZT). Some organic materials also are piezoelectric, in particular polyvinylidene fluoride (PVdF) which has a coupling effect coefficient about a fifth that of PZT. A simple transducer design incorporating a film of PVdF as the active element is described in J. Phys.E: Sci.Instrum., Vol. 14, 1981, pp.1313-9, (Bainton et al), the transducer having a broadband response (2-15MHz) but a low power output.

According to the present invention there is provided an ultrasonic transducer comprising a thin film of a piezoelectric organic material folded into a zig-zag with between three and ten layers, means for subjecting the film to an electrical signal, a couplant for coupling ultrasonic waves between adjacent layers, and means for clamping the layers together.

Preferably the material is polyvinylidene fluoride, the film being about 30 micrometres thick, and is coated on both surfaces with a coating of gold about 100 nm thick to which electrical contact is made. The optimum number of folded layers is five; a larger number of folds does increase the ultrasonic power output, but lowers the frequency response. Typically the zig-zag is clamped

between a backing block of brass or of polymethylmethacrylate (perspex), and a couplant block of polystyrene through which the ultrasonic waves are transmitted. Desirably the film contacts the couplant block only over a narrow strip, so as to define a "line source" of sound.

Such an ultrasonic transducer has a wide frequency response, typically 1-10 MHz (although this may be affected by absorption in the couplant block), and consequently can emit very short ultrasonic pulses enabling good resolution of the propagation time of ultrasonic signals for example in defect detection by the time-of-flight diffraction technique.

The invention will now be further described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 shows a longitudinal section view through an ultrasonic transducer; and

Figure 2 shows an exploded view, in section, of parts of the transducer of Figure 1.

Referring to Figure 1, an ultrasonic transducer 10 comprises a piezoelectric polyvinylidene fluoride film 12 clamped between a cylindrical brass backing block 14 and a generally cylindrical polystyrene coupling block 16, each of diameter 10 mm. The backing block 14 has a conical recess 18 in its surface remote from the film 12, and is located in a cylindrical recess in a rectangular block 20 of polystyrene. Above the block 20 is a square brass top-plate 22. The coupling block 16 is slightly tapered, and located in the bore of a polytetrafluoroethylene sleeve 24 which is of matching taper; the sleeve 24 is a tight

fit within a cylindrical bore through a rectangular brass face block 26 (being cooled in liquid nitrogen prior to being inserted as a sliding fit). These components are clamped together by four bolts 28 (only one of which is shown) which extend through holes in the top-plate 22 and the block 20 into threaded holes in the face-block 26. The coupling block 16 has a rectangular ridge 30 of width 2 mm across its top surface, and the film 12 is only in contact with the block 16 at the top of this ridge 30; the other end surface 31 of the block 16 is flat and oriented perpendicular to the longitudinal axis of the block 16.

Referring now to Figure 2, the film 12 is a rectangular strip 12 mm wide and 60 mm long, and is of thickness 25 micrometres. Each surface of the film 12 is coated by a cold sputtering technique with a coating of gold of thickness 100 nm (not shown), apart from a 2 mm wide uncoated margin along each edge. The film 12 is folded into a five-layer zig-zag, one end of the strip extending about twice the width of the zig-zag to enable electrical contact to the gold coatings to be made. Before assembly, a small quantity of a liquid shear-wave couplant is spread between successive layers of the zig-zag and onto the surfaces of the backing block 14 and of the ridge 30.

Referring again to Figure 1, electrical contact to the gold coatings of the film 12 is made by a probe 32 (which is an interference fit in a hole through the block 20) with a spring-loaded telescopic contact member 34; and by a deformable contact block 36 resting on the face-block 26. The film 12 is thus sandwiched between the spring-loaded contact member 34, and the contact block 36 which deforms to match the shape of the tip of the contact member 34. The contact block 36 might be of cork wrapped in indium foil, or might be of soft graphite. In use the face-block 26 is usually earthed, and a high voltage driver pulse of

for example 200 V may be supplied to the probe 32.

In operation of the transducer 10 as an emitter, when a driver pulse is supplied to the probe 32 the potential difference between the gold coatings on the surfaces of the film 12 causes the PVdF to undergo a mechanical strain, so generating an ultrasonic pulse. The ultrasonic waves propagate through the coupling block 16 into an object onto which the end surface 31 is placed in contact; the sleeve 24 being of an ultrasonically absorbent material tends to minimize spurious reflections and reverberations between the sides of the coupling block 16. The backing block 14 differs in acoustic impedance considerably from the PVdF film 12, so that most of the ultrasonic pulse propagates into the coupling block 16 (i.e. the forward direction) rather than into the backing block 14; the conical recess 18 reflects any backward-propagating ultrasonic waves radially outwards into the block 20. The transducer 10 can provide ultrasonic pulses of very short duration, as it has a wide bandwidth of about 1 MHz to about 7 MHz (the upper limit in this case being determined by absorption in the coupling block 16). The ultrasound enters the coupling block 16 only through the narrow ridge 30, so the location of the sound source is better defined than with a 10 mm diameter flat-topped coupling block.

It will also be understood that the transducer 10 is equally effective as a receiver of ultrasonic waves. A pair of transducers 10 operating as transmitter and receiver of ultrasonic waves are particularly suitable for use in the time-of-flight diffraction technique for detecting and sizing defects in an object, because the transducers 10 provide good temporal resolution; in addition the well-defined location of the sound source is advantageous in this respect.

It will be appreciated that the transducer 10 may be modified in various ways without departing from the present invention. In particular the coupling block 16 and the surrounding sleeve 24 and face block 26 may be different in thickness to that indicated by the Figure (though the thickness is preferably no less than 5 mm to ensure adequate compression of the film 12 can be achieved), and they may be cut so that the end surface 31 is at an angle to their longitudinal axis, so that ultrasound propagating along the longitudinal axis enters an object at a non-zero angle of incidence. Typically the angle of incidence would be chosen to be about 20 degrees, the angle of refraction within the object (for example of steel) being greater. Furthermore in the transducer 10 shown in the Figures the ridge 30 extends parallel to the fold lines of the film 12; alternatively the ridge 30 might be oriented perpendicular to the fold lines, and in this case the gold coating need only be provided along a strip of the film 12 of the same width as the ridge 30 i.e. 2 mm in this case.

It will also be appreciated that the ridge 30 might be of different width to that described: the narrower the ridge 30 the more accurately is the source location known, but the smaller is the amplitude of the emitted ultrasonic waves. Where a narrow ridge 30 is provided, it acts as a line source and so causes ultrasonic waves to propagate in substantially all directions through the coupling block 16, and so generating a divergent beam of ultrasound in the object. Consequently the width of the ridge 30 is preferably between about 1 mm and 3 mm.

Alternatively the ridge might be omitted, the coupling block 16 instead having a flat upper surface entirely in contact with the film 12. In this case the film 12 generates two types of ultrasonic wave in the block 16:

waves from the flat face in contact with the film 12, which propagate substantially along the longitudinal axis of the block 16, diverge only slightly, and form a well-defined beam in the object; and waves generated around the edge of that flat face, which as with a line source propagate in a wide and divergent range of directions both in the block 16 and the object. The transducer in this case is preferably operated so as to maximize the signal from the former type of wave.

Also the backing block 14 might be of a different material. For example it might be of perspex, which has a much lower acoustic impedance than brass, and which absorbs ultrasonic wave energy more than brass so that no conical recess 18 would be necessary. In this case ultrasonic waves emitted into the block 16 would be of lower amplitude, and would have a higher frequency spectrum, as the zig-zag film 12 would act as a half-wavelength resonator (modified by the coupling block 16), instead of acting as a quarter-wavelength resonator (similarly modified) when the backing block 14 is of brass.

Claims

1. An ultrasonic transducer comprising a thin film of a piezoelectric organic material folded into a zig-zag with between three and ten layers, means for subjecting the film to an electrical signal, a couplant for coupling ultrasonic waves between adjacent layers, and means for clamping the layers together.

2. A transducer as claimed in Claim 1 wherein the organic material is polyvinylidene fluoride.

3. A transducer as claimed in Claim 2 wherein the film is about 30 micrometres thick and has a thin coating of a metal on each surface.

4. A transducer as claimed in any one of the preceding claims wherein the zig-zag of the thin film is clamped between a backing block and a couplant block to couple ultrasonic waves from the film, wherein the couplant block contacts the film only along a narrow strip.

5. A transducer as claimed in Claim 4 wherein the narrow strip is defined by a rectangular ridge on the surface of the couplant block and of width about 2 mm.

6. An ultrasonic transducer substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.